NUMERICAL PROBLEMS

P.19.1 A particle called the pion lives on the average only about 2.6×10^{-8} s when at rest in the laboratory. It then changes to another form. How long would such a particle live when shooting through the space at 0.95c?

Sol:

$t_o = 2.6 \times 10^{-8}$ s

$v = 0.95c$

$t = ?$

As $t = \frac{t_o}{\sqrt{1 - v^2/c^2}}$

$$t = \frac{2.6 \times 10^{-8}}{\sqrt{1 - \frac{(0.95)^2 c^2}{c^2}}} = \boxed{8.3 \times 10^{-8}\ \text{s}}$$

P.19.2 What is the mass of a 70 kg man in a space rocket travelling at 0.8c from us as measured from Earth?

Sol:

$m_o = 70$ kg

$v = 0.8c$

$m = ?$

As $m = \frac{m_o}{\sqrt{1 - v^2/c^2}}$

$$m = \frac{70}{\sqrt{1 - \frac{(0.8)^2 c^2}{c^2}}} = \boxed{116.7\ \text{kg}}$$

P.19.3 Find the energy of photon in:

(a) Radio wave of wavelength 100 m.
(b) Green light of wavelength 550 nm
(c) X-ray with wavelength 0.2 nm

(P.T.O)

Sol. (a) $\lambda_1 = 100\,m$, $E_1 = ?$

As $E_1 = \frac{hc}{\lambda_1} = \frac{6.63\times10^{-34} \times (3\times10^{8})}{100}\,J$

In electron volt

$$E_1 = \frac{6.63\times10^{-34} \times (3\times10^{8})}{100 \times 1.6\times10^{-19}}\,eV$$

$$E_1 = \boxed{1.24\times10^{-8}\,eV}$$

(b) $$E_2 = \frac{hc}{\lambda_2} = \frac{6.63\times10^{-34} \times 3\times10^{8}}{550\times10^{-9} \times (1.6\times10^{-19})}\,eV$$

$$E_2 = \boxed{2.25\,eV}$$

(c) $$E_3 = \frac{hc}{\lambda_3} = \frac{(6.63\times10^{-34} \times (3\times10^{8}))}{0.2\times10^{-9} \times (1.6\times10^{-19})}\,eV$$

$$E_3 = \boxed{6200\,eV}$$

P.17.4 Yellow light of 577 nm wavelength is incident on a cesium surface. The stopping voltage is found to be 0.25 V. Find (a) The max. K.E of the photoelectrons (b) The work function of cesium.

Sol. $\lambda = 577\,nm = 577\times10^{-9}\,m$

$V_0 = 0.25\,V$

$e = 1.6\times10^{-19}\,C$

(a) $(K.E)_{max} = ?$

(b) $\phi = ?$

(a) As $(K.E)_{max} = V_0 \times e$

$= 0.25 \times 1.6\times10^{-19} = \boxed{4\times10^{-20}\,J}$

(b) Einstein eq. is

$$hf = (K.E)_{max} + \phi$$

$$\phi = \frac{hc}{\lambda} - (K.E)_{max}$$

$$= \frac{\left[\frac{6.63\times10^{-34} \times 3\times10^{8}}{577\times10^{-9}} - 4\times10^{-20}\right]}{1.6\times10^{-19}}\,eV = \boxed{1.91\,eV}$$

(P.T.O)

P.19.5 X-rays of wavelength 22 pm are scattered from a carbon target. The scattered radiation being viewed at 85° to the incident beam. What is Compton shift?

Sol.

$m_o = 9.1 \times 10^{-31}$ kg

$\theta' = 85°$

$\Delta\lambda = ?$

As

$$\Delta\lambda = \frac{h}{m_o c}(1 - \cos\theta)$$

$$= \frac{6.63\times10^{-34}}{9.11\times10^{-31} \times 3\times10^{8}}(1 - \cos 85°)$$

$$\Delta\lambda = \boxed{2.01\times10^{-12}\,m}$$

P:19:6 A 90 kev x-ray photon is fired at a carbon target and Compton scattering occurs. Find the wavelength of the incident photon and the wavelength of the scattered photon for scattering angle of (a) 30° (b) 60°

DATA: $E = 90\,kev = 90\times10^{3}\times1.6\times10^{-19}\,J$

$\lambda = ?$

(a) 30° (b) 60°

Sol. Energy of incident photon

$$E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E} = \frac{6.63\times10^{-34}\times3\times10^{8}}{90\times10^{3}\times1.6\times10^{-19}}$$

$$\lambda = \boxed{13.8\,Pm}$$

(a) Compton shift at $\theta = 30°$

$$\Delta\lambda = \frac{h}{m_o c}(1 - \cos\theta)$$

$$\lambda - \lambda' = \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times3\times10^{8}}(1 - \cos 30°)$$

$$\lambda' = \lambda - \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times3\times10^{8}}(1 - 0.866)$$

$$\lambda' = \boxed{14.1\,Pm}$$

where $\lambda' = 13.8\,Pm$

(b) $$\lambda' = 13.8 - \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times3\times10^{8}}(1 - \cos 60°)$$

$$\lambda' = \boxed{15\,Pm}$$

(P.T.O)

P.19.7 What is the max. wavelength of the two photons produced when a positron annihilates an electron? The rest mass energy of each is 0.51 MeV.

Sol: $\lambda = ?$

$E = 0.51\ \text{MeV} = 0.51 \times 10^{6} \times 1.6 \times 10^{-19}\ \text{J}$

As $E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E}$

$\lambda = \frac{6.63 \times 10^{-34} \times (3 \times 10^{8})}{0.51 \times 10^{6} \times 1.6 \times 10^{-19}} = \boxed{2.44 \times 10^{-12}\ \text{m}}$

P.19.8 Calculate the wavelength of:

(a) A 140 g ball moving at 40 m s^{-1}

(b) A photon moving at the same speed

(c) An electron moving at the same speed

Sol: As de Broglie wavelength

$\lambda = \frac{h}{mv}$

(a) $\lambda_1 = \frac{6.63 \times 10^{-34}}{0.14\ \text{kg} \times 40\ \text{m s}^{-1}} = \boxed{1.18 \times 10^{-34}\ \text{m}}$

(b) $\lambda_2 = \frac{6.63 \times 10^{-34}}{1.67 \times 10^{-27}\ \text{kg} \times 40\ \text{m s}^{-1}} = \boxed{9.92\ \text{m}}$

(c) $\lambda_3 = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31}\ \text{kg} \times 40\ \text{m s}^{-1}} = \boxed{1.82 \times 10^{-5}\ \text{m}}$

P.19.9 What is the de Broglie wavelength of an electron whose K.E is 120 eV?

Sol. $(K.E) = 120\ \text{eV} = 120 \times 1.6 \times 10^{-19} = 192 \times 10^{-19}\ \text{J}$

De Broglie wavelength $= \lambda = ?$

As $K.E = \frac{1}{2} m v^2$

$\Rightarrow v = \sqrt{\frac{2\,K.E}{m}} = \sqrt{\frac{2 \times 192 \times 10^{-19}}{9.11 \times 10^{-31}}} = 6.5 \times 10^{6}\ \text{m s}^{-1}$

We know that

$\lambda = \frac{h}{mv}$

$= \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 6.5 \times 10^{6}} = \boxed{1.12 \times 10^{-10}\ \text{m}}$

(P.T.O)

P.19.7 What is the max. wavelength of the two photons produced when a positron annihilates on electron? The rest mass energy of each is 0.51 MeV.

Sol. $\lambda = ?$

$E = 0.51\ MeV = 0.51 \times 10^{6} \times 1.6 \times 10^{-19}\ J$

As $E = \frac{hc}{\lambda}$ or $\lambda = \frac{hc}{E}$

$\lambda = \frac{6.63 \times 10^{-34} \times (3 \times 10^{8})}{0.51 \times 10^{6} \times 1.6 \times 10^{-19}} = \boxed{2.44 \times 10^{-12}\ m}$

P.19.8 Calculate the wavelength of

(a) A 140 g ball moving at $40\ m\,s^{-1}$

(b) A photon moving at the same speed

(c) An electron moving at the same speed.

Sol. As de Broglie wavelength

$\lambda = \frac{h}{mv}$

(a) $\lambda_1 = \frac{6.63 \times 10^{-34}\ J\,s}{0.14\ Kg \times 40\ m\,s^{-1}} = \boxed{1.18 \times 10^{-34}\ m}$

(b) $\lambda_2 = \frac{6.63 \times 10^{-34}}{6.7 \times 10^{-27}\ Kg \times 40\ m\,s^{-1}} = \boxed{9.92\ m}$

(c) $\lambda_3 = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31}\ Kg \times 40\ m\,s^{-1}} = \boxed{1.82 \times 10^{-5}\ m}$

P.19.9 What is the de Broglie wavelength of an electron whose K.E is 120 eV?

Sol. $(K.E)_e = 120\ eV = 120 \times 1.6 \times 10^{-19} = 192 \times 10^{-19}\ J$

De-Broglie wavelength $= \lambda = ?$

As $K.E = \frac{1}{2} mv^2$

$\Rightarrow v = \sqrt{\frac{2\ K.E}{m}} = \sqrt{\frac{2 \times 192 \times 10^{-19}}{9.11 \times 10^{-31}}} = 6.5 \times 10^{6}\ m\,s^{-1}$ (1)

We know that

$\lambda = \frac{h}{mv}$

$= \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 6.5 \times 10^{6}} = \boxed{1.12 \times 10^{-10}\ m}$

(P.T.O)

P. 19.10 An electron is placed in a box about the size of an atom that is about 1.0×10^{-10} m. What is the velocity of the electron?

Sol.

$\lambda = 1.0 \times 10^{-10}$ m

vel. of an electron $V = ?$

Using the rel;

$$P = \frac{h}{\lambda}$$

$$\text{or} \quad \lambda = \frac{h}{P} = \frac{h}{mv}$$

$$\Rightarrow \quad V = \frac{h}{m\lambda} \quad \text{——— (1)}$$

$$= \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 1.0 \times 10^{-10}}$$

$$V = \boxed{7.29 \times 10^{6}\ \mathrm{m\,s^{-1}}}$$